P38.12
2.3 M46

Mineral Resource Report M 46

1963

Underground Gas Storage in Pennsylvania

William S. Lytle

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
Genevieve Blatt, Secretary

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

DOCUMENTS SECTION

BULLETIN M 46

Underground Gas Storage in Pennsylvania

by William S. Lytle
Staff geologist
Pa. Geological Survey

PENNSYLVANIA GEOLOGICAL SURVEY
FOURTH SERIES
HARRISBURG
1963

Copyrighted 1963

by the

Commonwealth of Pennsylvania

Quotations from this book may be published if credit is given

to the Pennsylvania Geological Survey

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PURCHASED FROM
BUREAU OF PUBLICATIONS
DEPARTMENT OF PROPERTY AND SUPPLIES
HARRISBURG, PA.

CONTENTS

	Page
Abstract	1
Introduction	1
Acknowledgments	2
Gas production in Pennsylvania	4
Structure and stratigraphy as related to gas storage	5
Stratigraphy	14
Unconformities	18
Structure	18
Gas storage projects in Pennsylvania	19
Regulation of underground gas storage pools	29
Conclusions	30
References	31

ILLUSTRATIONS

FIGURES

		Page
Figure 1.	The Corry storage field	18

PLATES

Plate	1.	Gas storage fields in Pennsylvania	*in pocket*
	2.	Annual production of natural gas in Pennsylvania	3
	3.	Principal natural gas pipelines of Pennsylvania	*in pocket*
	4.	Physical divisions of Pennsylvania	6
	5.	Geologic map of Pennsylvania	7
	6.	Columnar sections showing stratigraphic positions of oil and gas of western Pennsylvania	15
	7.	Columnar section obtained in the Jessie D. Hockenberry well no. 1 in western Pennsylvania	16
	8.	The Harrison storage pool	24
	9.	The Hebron storage pool	25
	10.	The Leidy and Greenlick storage pools	*in pocket*
	11.	The Meade storage field	26
	12.	The Sabinsville storage field	27
	13.	The Sharon storage field	28
	14.	The East Tioga, West Tioga, and Meeker storage pools	*in pocket*

Digitized by the Internet Archive
in 2016 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/undergroundgasst00lytl

UNDERGROUND STORAGE OF NATURAL GAS IN PENNSYLVANIA

by William S. Lytle

ABSTRACT

At the close of 1960 Pennsylvania had 61 active natural gas storage pools. The gas is stored in depleted gas pools in rocks from Silurian to Pennsylvanian age from 1,000 feet to 6,000 feet in depth. The storage pools occupy stratigraphic rather than structural traps in Pennsylvanian, Mississippian, Upper Devonian, and Lower Silurian (Medina) strata. In contrast, the gas stored in the Oriskany Sandstone (Lower Devonian in age) pools occupies structural traps consisting of elongated domes along the prominent anticlines. (See Figure 1 and Plates 8-14.)

Pennsylvania is the ranking state in all phases of gas storage. The following figures for 1960 are published by the AGA for Pennsylvania: the maximum gas storage, 485,000,000 Mcf; total input, 227,000,000 Mcf; maximum daily output, 2,859,000 Mcf; total output, 177,000,000 Mcf; and ultimate capacity, 497,000,000 Mcf.

INTRODUCTION

Following the drilling of the world's first commercial oil well, the Drake Well at Titusville, Pennsylvania, in 1859, rapid discovery and development of Pennsylvania's oil and gas fields took place. Most of the state's shallow oil and gas fields were discovered and developed before the turn of the century. Gas was piped 5½ miles to Titusville, Pennsylvania, in 1872 and about 11 miles from Murrysville to Pittsburgh in 1883.

To store natural gas in the early days, the natural gas industries used gas holders, pipelines, auxiliary artificial gas plants, and gas wells which were used only during periods of peak seasonal or daily demand. In 1915 gas was first successfully stored underground in Welland County, Ontario, Canada. The second underground storage of natural gas was effected in the Zoar Field in Buffalo, New York, in 1916.

During the First World War serious natural gas shortages developed, and curtailments were necessary. After the war the demands for natural gas decreased, and the supply situation improved, but even in these years meeting the peak during periods of cold weather was a major problem of the gas companies. To the operators of the gas systems it became apparent that storage pools were needed that would deliver large volumes of gas for a few days at a time. Relatively small storage pools were developed to meet the situation.

There were 2,045,000 residential consumers in Pennsylvania during 1960, utilizing 232,046,000 M cubic feet of gas at an average value of 107.1 cents per thousand cubic feet (Minerals Yearbook, v. 2, Fuels, 1960). Commercial consumers totaled 122,000 during the year. They used 56,134,000 M cubic feet of gas valued at 85.8 cents per thousand. Other users of natural gas in Pennsylvania during 1960 include the producers, drillers, refiners, pipeliners and other industrial users. During the year they consumed 232,608,000 M cubic feet valued at 52.2 cents per thousand.

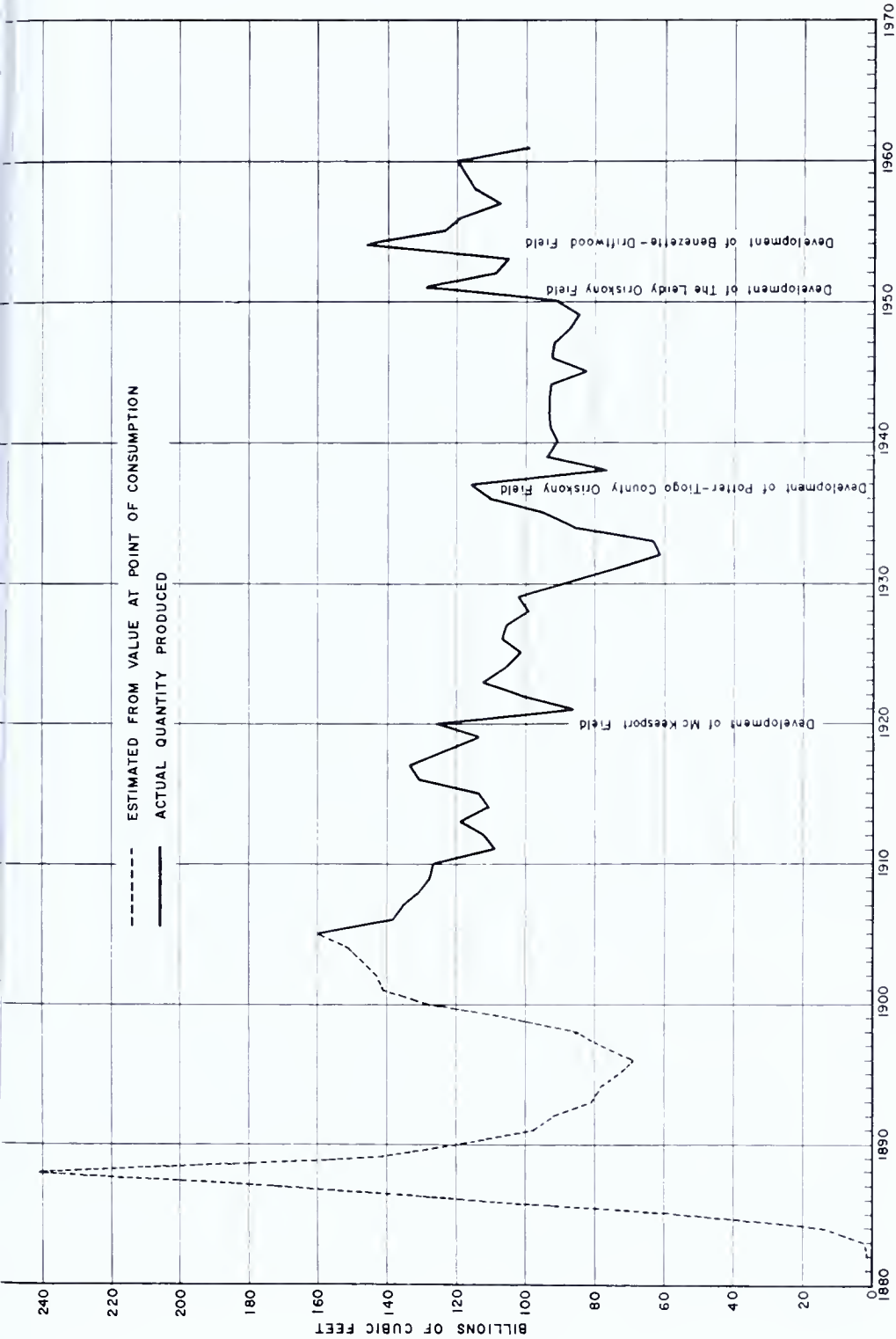
The marketed production of gas in Pennsylvania in 1960 amounted to 113,928,000 M cubic feet and was valued at 31.8 cents (average) per thousand cubic feet at the well head. Interstate movement of gas amounted to 55,962,000 M cubic feet shipped and 498,607,000 M cubic feet received. The gas received came mostly from the west-south-central, the south Atlantic, and east-south-central states including Mexico, Texas, Gulf of Mexico, and Louisiana. Consumption within Pennsylvania amounted to 520,788,000 M cubic feet or 4½ times marketed production. The estimated value of the gas at the points of consumption amounted to $418,015,000.00 or an average of 80.3 cents per thousand cubic feet.

The Central Kentucky Natural Gas Company of Lexington was one of the first companies to utilize underground storage by developing such storage in the Menifee Field, Kentucky, in 1919. Pennsylvania's first storage project was developed the following year by the United Natural Gas Company when it converted the Queen gas pool in Warren and Forest Counties to a gas storage pool.

Little was done about underground storage of natural gas in Pennsylvania, or in the rest of the Appalachian area, until 1934 when several storage pools were put into operation. The rapid growth in popularity of underground gas storage during the past 27 years has centered around the depleted oil and gas fields in or near the large market areas. Today there are 61 natural gas storage pools in Pennsylvania. Additional pools are under development. The names and locations of the natural gas storage projects and the locations of the oil and gas fields are shown on Plate 1.

ACKNOWLEDGEMENTS

The writer acknowledges the cooperation in the preparation of this report, of Addison S. Cate and Walter R. Wagner whose structure maps of the gas storage fields appear in the report and of all the gas companies for the data on the gas storage fields. Virginia Fairall and Lillian Heeren of the Pennsylvania Bureau of Topographic and Geologic Survey did the drafting and assisted with the compiling of the data.



ANNUAL PRODUCTION OF NATURAL GAS IN PENNSYLVANIA

Plate 2

GAS PRODUCTION IN PENNSYLVANIA

Apparently the first well actually drilled for natural gas, and used for a number of years, was the well drilled at Fredonia, New York, about 1824. The yearly charge for the gas per house was $1.50. One account states that lead pipe was used for the transportation of the gas. In 1831 at Erie, Pennsylvania, natural gas was piped from a spring through wooden pipes and burned in a lighthouse. Pennsylvania's first gas field was discovered in Erie County in 1860 at shallow depths along Lake Erie. This gas supplied several factories in the area. Gas was used to fire boilers to pump the oil wells along Oil Creek in 1862. In 1867 D. G. Stillwell drilled a gas well within what is now the limits of Oil City, Pa., and piped the gas to a number of homes where it was used for cooking and heating purposes. The Newton gas well in 1872 struck gas which was piped 5½ miles to Titusville, Pa., by a company organized for the express purpose of transporting the gas. Gas from this well furnished fuel and light to about 250 customers. The first application of natural gas to iron making was made by Rogers & Birchfield in their puddling furnaces at Leechburg, Pa., in 1872. Gas was piped for 19 miles through a 6-inch pipe in 1875 from Lardintown, Butler County, Pa., to the Spang, Chalfant & Co., iron works at Sharpsburg, Pa., (now Etna) and the Graff, Bennett & Co., iron works at Allegheny (now Millvale), Pa. In 1883 attention was directed towards supplying natural gas to Pittsburgh. Men recalled the facts about the large production of gas which came from the Haymaker Well No. 1 at Murrysville when it was drilled in on November 3, 1878. New wells were drilled in the Murrysville area and gas from them and the Haymaker well was piped into Pittsburgh in 1884. This gave the necessary boost to the gas industry causing the rapid development and use of natural gas.

No statistics were kept on the quantity and value of the natural gas produced until 1882. From 1882 to 1906 only the value of gas produced was recorded. From these values it was computed that the peak year of natural gas production in the state was 1888 when approximately 241,000,000 Mcf of gas were produced. A secondary peak occurred in 1906 when the production amounted to 138,161,385 Mcf. From 1906 to 1932 the production gradually declined to about 61,000,000 Mcf. The discovery of Oriskany gas in the state increased the production to about 115,000,000 Mcf in 1937 and to over 158,000,000 Mcf in 1954. The cumulative total production of natural gas in the state by the end of 1960 was 7,410,420,000 Mcf. The reserve figure for the same date as published by the AGA is 1,192,480,000 Mcf. During the 79 years from 1882 to 1960 inclusive, the annual natural gas production has been below 100,000,000 Mcf 20 times, but has never fallen below 60,000,000 Mcf.

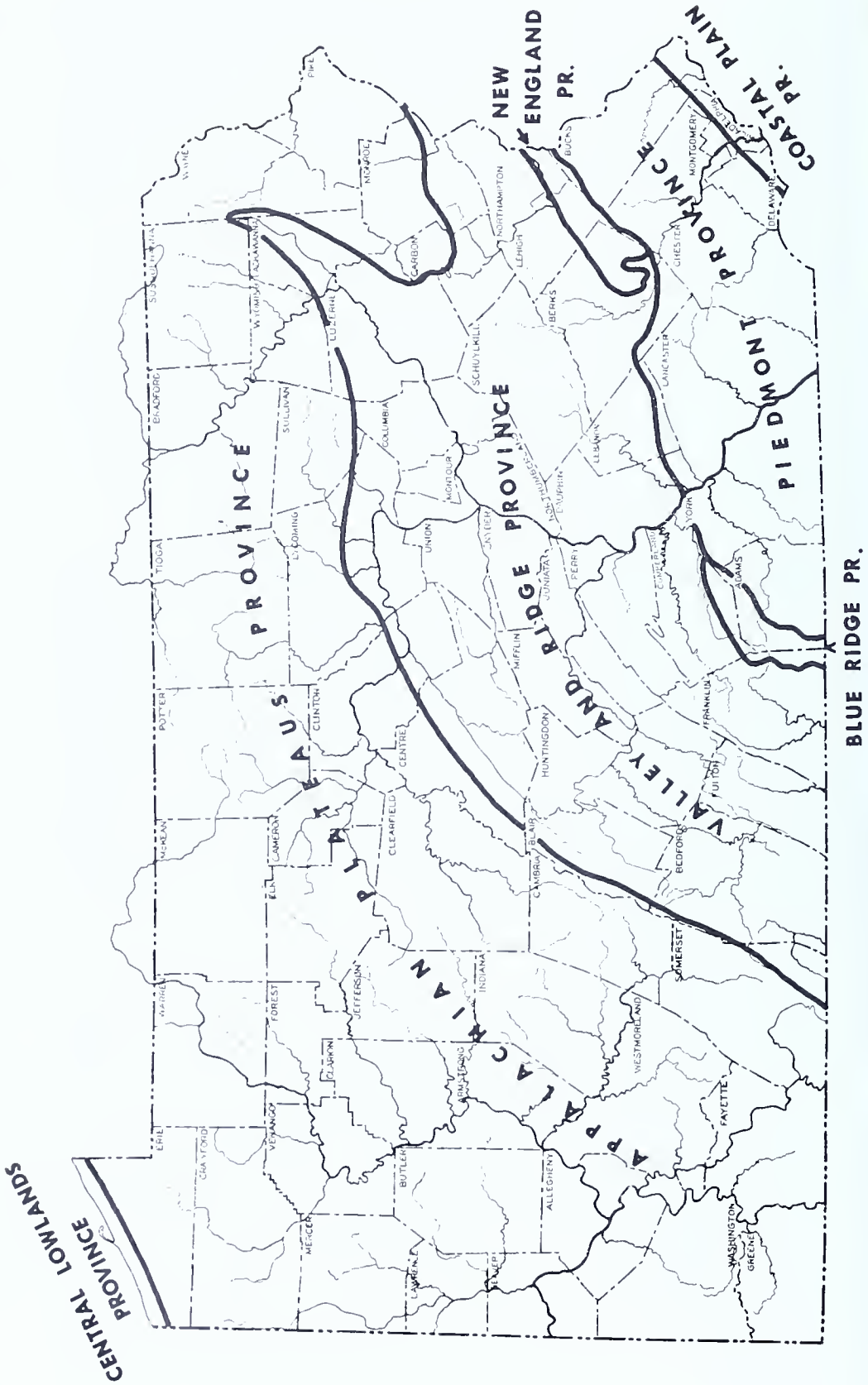
The amount of natural gas consumed in Pennsylvania exceeded the volume of manufactured gas consumed (on an equivalent heat unit basis) in 1884. In 1883 the volume of natural gas consumed was approximately 2,500,000 Mcf while in 1884 the consumption was approximately 14,000,000 Mcf. By 1898 the use of natural gas in the state had increased to over 85,000,000 Mcf per year (Plate 2) while the use of manufactured gas had decreased to 2,818,952 Mcf for the year.

Oriskany sand production (Lower Devonian) was discovered in September 1930 in Tioga County. Discoveries in the deeper horizon have continued. Today a number of these discoveries are gas storage pools. By the end of 1959 the Leidy Field had produced a cumulative total of 153,500,000 Mcf of gas from the Oriskany sand. As of the same date the Benezette-Driftwood Pool had produced 217,000,000 Mcf of gas from the Oriskany. Exploratory work is continuing in the deeper horizons in an effort to find additional oil and gas.

Since 1921 Pennsylvania has consumed more gas than it has produced. Until 1943 the supply was augmented by gas from other states in the Appalachian area. The first deliveries of gas from the western part of the United States took place in 1943. Today over one billion cubic feet of gas are purchased daily by the gas companies from sources outside the state. The chief suppliers are Tennessee Gas Transmission, Texas Eastern Gas Transmission, and Transcontinental Pipeline. Plate 3 shows the location of the principal natural gas pipelines in the state. Most of the gas brought into the state has been transported some 1,400 miles from Mexico, Texas, Gulf of Mexico, and Louisiana. About 85% of the natural gas used in Pennsylvania today comes from sources outside the state.

STRUCTURE AND STRATIGRAPHY AS RELATED TO GAS STORAGE

The state has been divided into physiographic provinces as shown on Plate 4. The largest of these, the Appalachian Plateaus Province, is an area in which sedimentary rocks dip gently to the south. In the southeastern part of the province the rocks have been gently folded into NE-SW trending anticlines and synclines. This part of the province is known as the Allegheny Mountains Section. The Valley and Ridge Province contains highly folded sedimentary rocks ranging in age from Cambrian to Pennsylvanian. The Piedmont Province consists of highly contorted and altered sedimentary rocks and some igneous rocks; a belt covering approximately the northern one third of the area contains Triassic sedimentary rocks.


CENTRAL LOWLANDS PROVINCE
APPALACHIAN PLATEAUS PROVINCE
VALLEY AND RIDGE PROVINCE
PIEDMONT PROVINCE
COASTAL PLAIN PR.
NEW ENGLAND PR.
BLUE RIDGE PR.
ERIE
CRAWFORD
MERCER
VENANGO
BUTLER
LAWRENCE
BEAVER
ALLEGHENY
WASHINGTON
GREENE
FAYETTE
WESTMORELAND
SOMERSET
BEDFORD
FULTON
FRANKLIN
ADAMS
YORK
CUMBERLAND
PERRY
JUNIATA
MIFFLIN
HUNTINGDON
CAMBRIA
BLAIR
INDIANA
ARMSTRONG
CLARION
JEFFERSON
FOREST
WARREN
ELK
CAMERON
CLEARFIELD
CENTRE
CLINTON
POTTER
McKEAN
TIOGA
LYCOMING
UNION
SNYDER
MONTOUR
COLUMBIA
SULLIVAN
BRADFORD
SUSQUEHANNA
WYOMING
LUZERNE
WAYNE
PIKE
MONROE
CARBON
SCHUYLKILL
NORTHUMBERLAND
DAUPHIN
LEBANON
LANCASTER
LEHIGH
NORTHAMPTON
BERKS
CHESTER
MONTGOMERY
BUCKS
DELAWARE

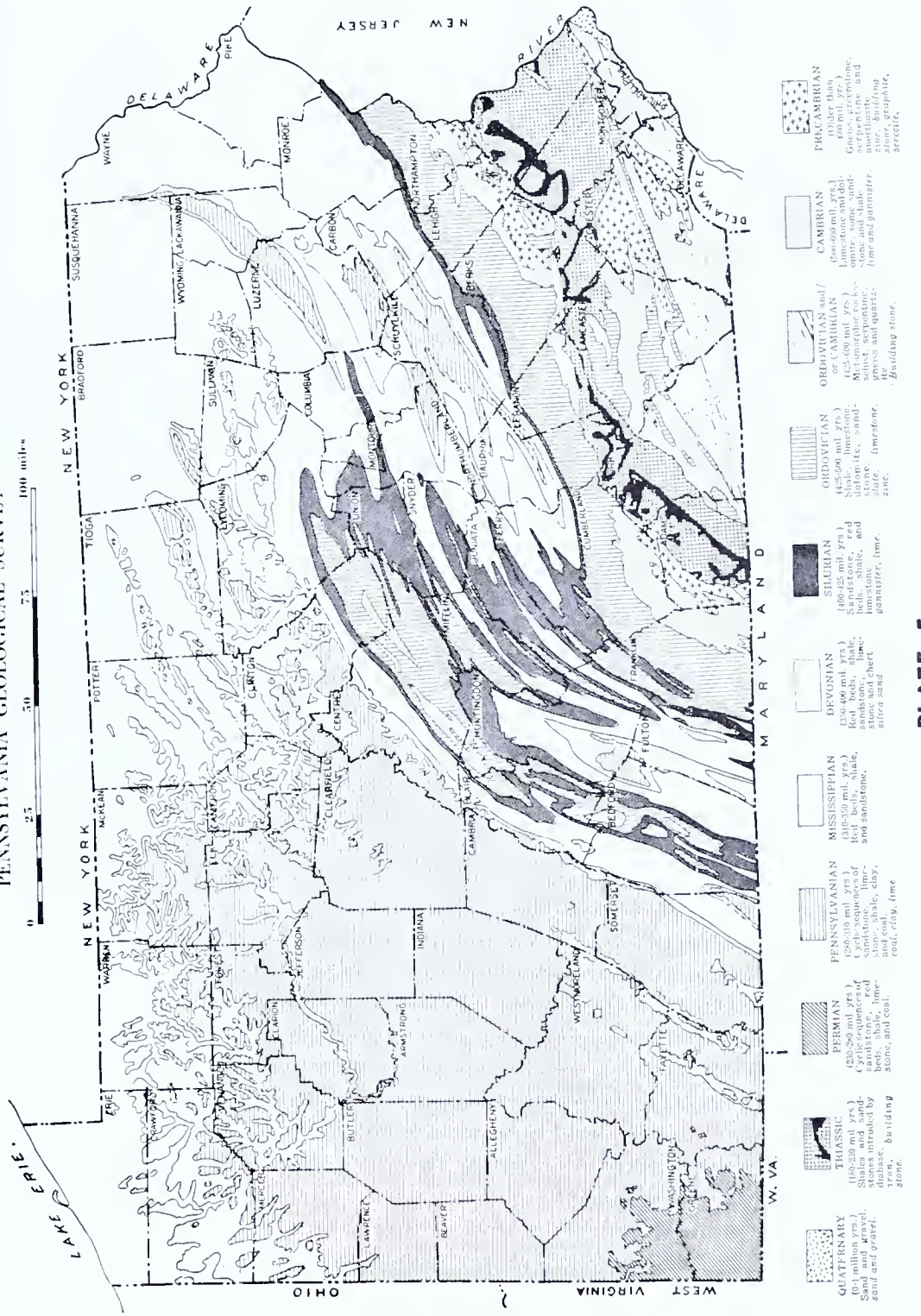

Geologic Map of Pennsylvania
PENNSYLVANIA GEOLOGICAL SURVEY
0 25 50 75 100 miles
LAKE ERIE
NEW YORK
NEW JERSEY
DELAWARE RIVER
MARYLAND
W. VA.
OHIO
WEST VIRGINIA
QUATERNARY (0-1 million yrs.) Sand and gravel, sand and gravel.
TRIASSIC (160-200 mil. yrs.) Shales and sandstones intruded by diabase.
PERMIAN (230-260 mil. yrs.) Cyclic sequences of sandstone, red beds, shale, limestone, and coal.
PENNSYLVANIAN (250-310 mil. yrs.) Cyclic sequences of sandstone, shale, clays, and coal.
MISSISSIPPIAN (310-350 mil. yrs.) Red beds, shale, and sandstone.
DEVONIAN (350-400 mil. yrs.) Red beds, shale, sandstone, limestone, silica sand.
SILURIAN (400-425 mil. yrs.) Shale, red beds, and limestone.
ORDOVICIAN (425-500 mil. yrs.) Shale, limestone, dolomite, sandstone.
ORDOVICIAN and/or CAMBRIAN (425-500 mil. yrs.) Metamorphic rocks, schist, serpentine, gneiss, and quartzite.
CAMBRIAN (500-600 mil. yrs.) Limestone and dolomite, sandstone, conglomerate, and shale.
PRECAMBRIAN (older than 600 mil. yrs.) Gneiss, sandstone, serpentine and amorphosite.

PLATE 5

Table 1—*General Geologic Section for North-Central and Western Pennsylvania with Reference to Gas Storage*

System	Series	Group or Formation	Description and Approximate Thickness Feet	Remarks on Gas Storage
Quarternary	Recent and Pleistocene		Clays, silts, sands, gravels, boulders in surficial deposits mostly unconsolidated, comprising soil, outwash, lake deposits, stream terraces, and the glacial deposits of northwestern and northeastern Pennsylvania. 0-200±	Fresh-water-bearing beds of great importance yield up to 2500 gals. per minute, not suited for gas storage because of shallow depth and lack of impervious sealing beds.
Permian	Dunkard	Greene	Predominately shale, in part red, sandy shale, and shaly sandstone; a few massive sandstones; several thin coal and freshwater limestone beds. 1,000	Present only in southwestern Pa. Although generally at shallow depths, one of the more massive sandstones might have storage possibilities.
		Washington	Shales, sandstones, and thin beds of coal and freshwater limestone.	
Pennsylvanian		Monongahela	Shale, and fresh-water limestone, subordinate sandstone, several workable coal beds. Waynesburg coal at top and Pittsburgh coal at base. 300	A sandstone with storage possibilities should be present in these freshwater reservoirs in southwestern Pa.
		Conemaugh	Shale, in part red, and subordinate sandstone; several thin coal and fresh-water and marine limestone beds; contains Murphy, Little Dunkard and Big Dunkard sands in descending order in southwestern district. 600	In southwestern Pennsylvania some of the sandstones in these groups produce oil and gas. Locally they are used as gas storage reservoirs in stratigraphic traps. Additional reservoirs in this area should be suitable for gas storage. In the northwestern part of the State the beds produce fresh or brackish water.
		Allegheny	Shale and subordinate sandstone and limestone; several workable coal and fire clay beds. Upper Freeport coal at top and Brookville coal at base. Contains First Gas sand in lower part in southwestern district. 275	
		Pottsville	Massive medium- to coarse-grained sandstone and subordinate shale, clay and limestone. Contains First and Second Salt, and Maxton sands in southwestern district. 215	

Unconformity			An erosional unconformity bevels successively younger, southerly dipping Mississippian strata in going from north to south in western Pennsylvania. In McKean County, Pottsville sandstone rests upon the Knapp formation, the lowest member of the Mississippian system; while in Fayette County, the Pottsville overlies the Mauch Chunk red shale, the highest member.		
Mississippian		Mauch Chunk	Gray and red shale, subordinate fine-grained sandstone. 0-100		Sandstones throughout the section, in the southern two-thirds of western Pennsylvania, offer several reservoirs. The Big Injun and Murrysville sandstones are being used locally as gas storage reservoirs.
		Greenbrier	Consists in descending order of limestone, a shale break, and the Loyalhanna sandy limestone. 0-80		
		Pocono	Fine- to coarse-grained massive sandstone and shale, Knapp sandstone and shale at base. Contains Big Injun, Squaw, Berea, Gantz, and Murrysville sands in southwestern district. 570-900		
Devonian	Upper Devonian	Conewango	Gray shale and subordinate fine- to coarse-grained light gray sandstone; red shale prominent in lower part in northern district; some purplish-red shale in middle and southwestern districts. Contains the Venango First, Second, and Third sands in the Middle district, Gantz, Fifty-foot, Upper and Lower Ninevah, Gordon and McDonald Fourth and Fifth sands in the southwestern district. Includes Chemung Formation.	Upper Devonian—3300-6000 from NW to SE.	Except in the extreme northwestern part of the state. sandstones throughout the section offer many reservoirs. Most of the current gas storage projects utilize stratigraphic traps found in this group. Extremely important in Pittsburgh area.
		Conneaut	Gray and purplish-gray shale and sandy shale, subordinate sandstone. Contains the Bradford First or Glade sand in the northern district, Queen sand in the middle district, Bayard and Elizabeth sand in the southwestern district. Includes Portage Formation.		Sandstones in lower part bear oil and gas. Suitable stratigraphic trap type storage reservoirs present over most of western and northwestern Pennsylvania.

Table 1—*General Geologic Section for North-Central and Western Pennsylvania (Continued)*

System	Series	Group or Formation	Description and Approximate Thickness Feet		Remarks on Gas Storage
Devonian	Upper Devonian	Canadaway	Gray shale and sandy shale, subordinate fine- to coarse-grained light gray sandstone and fine-grained chocolate-brown sandstone. Contains the Clarendon, Cherry Grove, Bradford Second, Cooper, Bradford Third, Kane, and Haskill sands in the northern district. Speechley and Bradford sands in the southwestern district.	See previous page	In the upper part of the section many sandstones bear oil and gas and are suitable reservoirs for storage. Stratigraphic traps in these sandstones are utilized for storage mostly in northwestern Pennsylvania.
		Genesee	Gray shale and sandy shale, subordinate fine-grained sandstone, dark gray and black shale.		Mostly shale and fine-grained sandstones of low porosity.
	Middle Devonian	Tully	Argillaceous limestone.	0-150	Mostly shale and argillaceous limestone.
		Hamilton	Dark gray and black shale, in part calcareous.	100-2000	
		Onondaga	Cherty limestone and chert, subordinate dark, silty, shaly and glauconitic beds. Source of gas in fields in Clearfield, Indiana, Westmoreland and Fayette Counties.	8-290	Has future storage possibilities. Is gas productive in fracture porosity.
	Lower Devonian	Oriskany	Medium-grained quartz sandstone, locally calcareous. Source of gas from north-central to southwestern Pennsylvania, and in Erie County.	0-175	Gas productive in numerous areas, deeply buried, states most important storage horizon.
		Helderberg	Non-magnesian, in part cherty, frequently very fossiliferous limestone.	0-350	Of little interest.
Silurian	Upper Silurian or Cayugan	Bass Island or Keyser	Argillaceous dolomitic limestone.	20-450	Of little interest.

Silurian	Upper Silurian or Cayugan	Salina	Interbedded, dense, argillaceous, magnesian limestone, gray shales, and clays for the most part either calcareous or dolomitic. Numerous interbedded layers of anhydrite and salt. Small gas production in McCance field, Westmoreland County.	450-2000	Thick salt deposits suited for liquid storage in washed-out cavities. Natural gas storage not probable at this time.
	Middle Silurian or Niagaran	Lockport	Very fine, crystalline, brownish-gray to very dark grayish brown, relatively pure dolomite. A salt-water zone frequently present. Small gas production in Mercer County.	240-320	Of little interest. Possible reservoir in salt-water zone.
		Clinton	Shale, dolomitic shale, and subordinate dolomite.	100-300	
	Lower Silurian or Albion	Grimsby	Red and gray sandstone and shale. Gas and minor oil production in northwestern Pennsylvania.	70-220	Of interest in extreme northwestern Pa. where beds are about 3500 feet in depth. One storage project utilizing the Medina section.
		Cabot Head	Gray shale and subordinate very fine-grained light-gray sandstone.		
		Whirlpool	Fine-grained light-gray sandstone. Minor gas production in northwestern Pennsylvania.		
Ordovician	Upper Ordovician or Cincinnatian	Queenston	Red shale, in part silty and sandy.	850-1200	Of little interest. Mostly fine-grained sandstones and shales.
		Oswego	Very fine-grained gray sandstone.	0-60	
		Reedsville	Gray shale.	700-800	
		Utica	Black shale.	100-300	

Table 1—*General Geologic Section for North-Central and Western Pennsylvania (Continued)*

System	Series	Group or Formation	Description and Approximate Thickness Feet		Remarks on Gas Storage
Ordovician	Middle Ordovician or Champlainian (and possibly upper Canadian)	Trenton	Fine to very fine crystalline, argillaceous, and fossiliferous, brownish gray limestone, with interbedded dark gray to grayish black calcareous shale. At base is usually a 20′ to 50′ zone with a little interbedded light gray bentonite or silty limestone. In Erie Co., top 10′ to 15′ is dolomitic. Thickness increases from 250′ to 440′ in north to northwesterly direction. Greatest thickness in Erie and northern Warren Counties. 200 to 440	650–800	Of little interest due to extreme depths over most of western Pennsylvania. No commercial production found to date in these beds. Possible storage in mined cavities.
		Black River and Chazy ?	Dense to very fine crystalline, occasionally fossiliferous, light brownish to brownish gray limestone. In northwestern Pa. the lower part contains some interbedded dolomite and dolomitic limestone. Thickens from 275′ to 500′ in southerly direction. Greatest thickness in Northern Butler and southern Mercer County. 200 to 350		
		Chazy ? and Upper Beekmantown?	Silty and sandy dolomite and limestone in upper part; dolomitic shale and silty shale in lower part, with a dolomitic sandstone commonly found at base. Thickness 30′ to 150′; axis of greatest thickening in northeast-southwest direction through southern Warren Co., northwestern Venango Co., and southwestern Crawford Co., and northern Mercer Co.		
	Unconformity		Approximately 4500 feet of Lower Ordovician strata present in central Pa., are missing in western Pa.		
	Lower Ordovician or Canadian	Lower Beekmantown	Fine to medium crystalline, siliceous, light gray dolomite. Thickens in southerly and easterly direction from northwest corner of Pennsylvania. 0-190		Same as Middle Ordovician

Cambrian	Upper Cambrian		Gatesburg	Upper member—Dolomitic sandstone and/or fine to medium crystalline, sandy dolomite, light brownish gray. 60 to 200 Middle member—Fine to medium crystalline, sandy, oolitic to mottled, brownish to light brownish gray dolomite, with dolomitic limestone at base. 200 Lower member—Fine to medium grained sandstone, with interbedded sandy dolomite and a little gray shale. 100	Where penetrated the Gatesburg Sandstone has produced salt water and on occasions had shows of gas. Although at great depth, this horizon might be of interest in the future.
		Warrior	Eau Claire	Dark brownish to brownish gray dolomite, in part sandy and oolitic; some interbedded gray shale and shaly dolomite especially near top. 400±	
			Mt. Simon	Light- to very light-gray sandstone, fine to coarse grained, dolomitic to siliceous. 100±	
Unconformity				Approximately 9000′ of Lower and Middle Cambrian strata present in South Mountain area of south-central Pa. are absent from western and north-central Pa.	Possible storage in mined cavities.
Precambrian				Igneous and/or metamorphic rocks.	Possible storage in mined cavities.

Revised by Walter R. Wagner, 1960, after C. R. Fettke, 1956, adopted for this report by William S. Lytle, 1960

The rocks exposed at the surface in Pennsylvania range in age from Precambrian to Recent (Plate 5). At the present time all of the natural gas storage is in sedimentary rocks in the Appalachian Plateau Province. Two storage areas lie along the western edge of the Allegheny Mountains Section.

STRATIGRAPHY

The succession and nature of the formations underlying the Appalachian Basin in Pennsylvania are shown in Table 1 along with data pertinent to natural gas storage. The stratigraphic positions of the more important oil and gas bearing sands as developed in Pennsylvania are shown in Plate 6 for the part of the column which contains the Upper Devonian and in Plate 7 for older producing horizons.

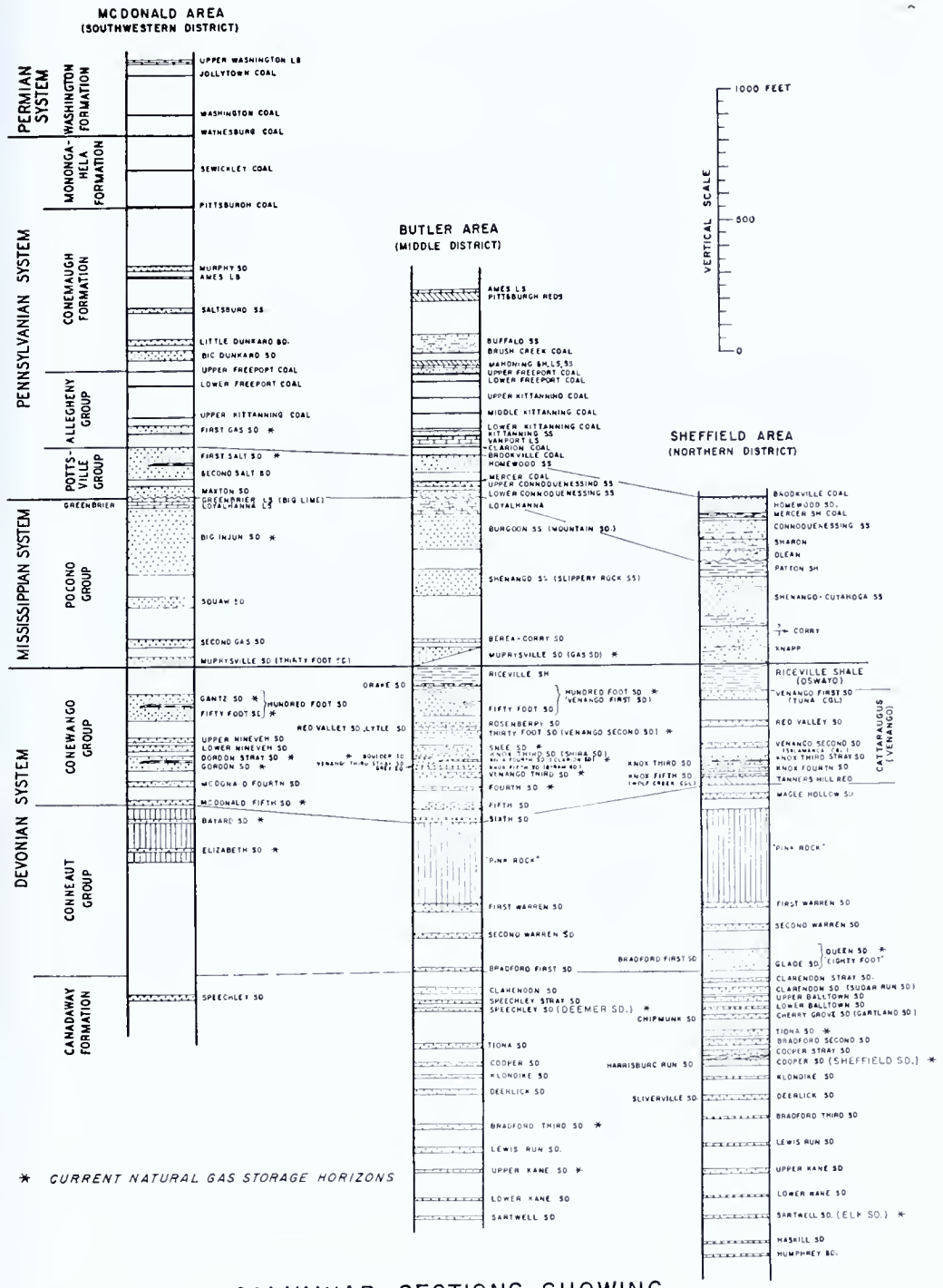
In central Pennsylvania, in the closely folded Appalachian Mountains, the exposed Upper Cambrian to Mississippian section has a thickness of over 30,000 feet. The corresponding interval in central Ohio includes less than 5,000 feet of strata due to the thinning of many of the formations westward and the cutting out of others by unconformities.

The reservoir rocks in which oil and gas in commercial quantities have been found in Pennsylvania range in age from Pennsylvanian to Silurian.

In southwestern Pennsylvania the sandstones in the Pennsylvanian System have yielded substantial volumes of gas and oil. Gas is being stored in these sandstones in storage pools located in Greene and Washington Counties. In the central part of western Pennsylvania these same sandstones yield fresh or brackish water, while in the northwestern part of the state they have been eroded or were never deposited.

The Mississippian sandstones have been important sources of both gas and oil in western Pennsylvania. The Big Injun and Berea have yielded considerable quantities of oil. The Murrysville sandstone at the base of the Mississippian has been a great producer of gas and is now being used as a storage reservoir in the southwestern part of the state.

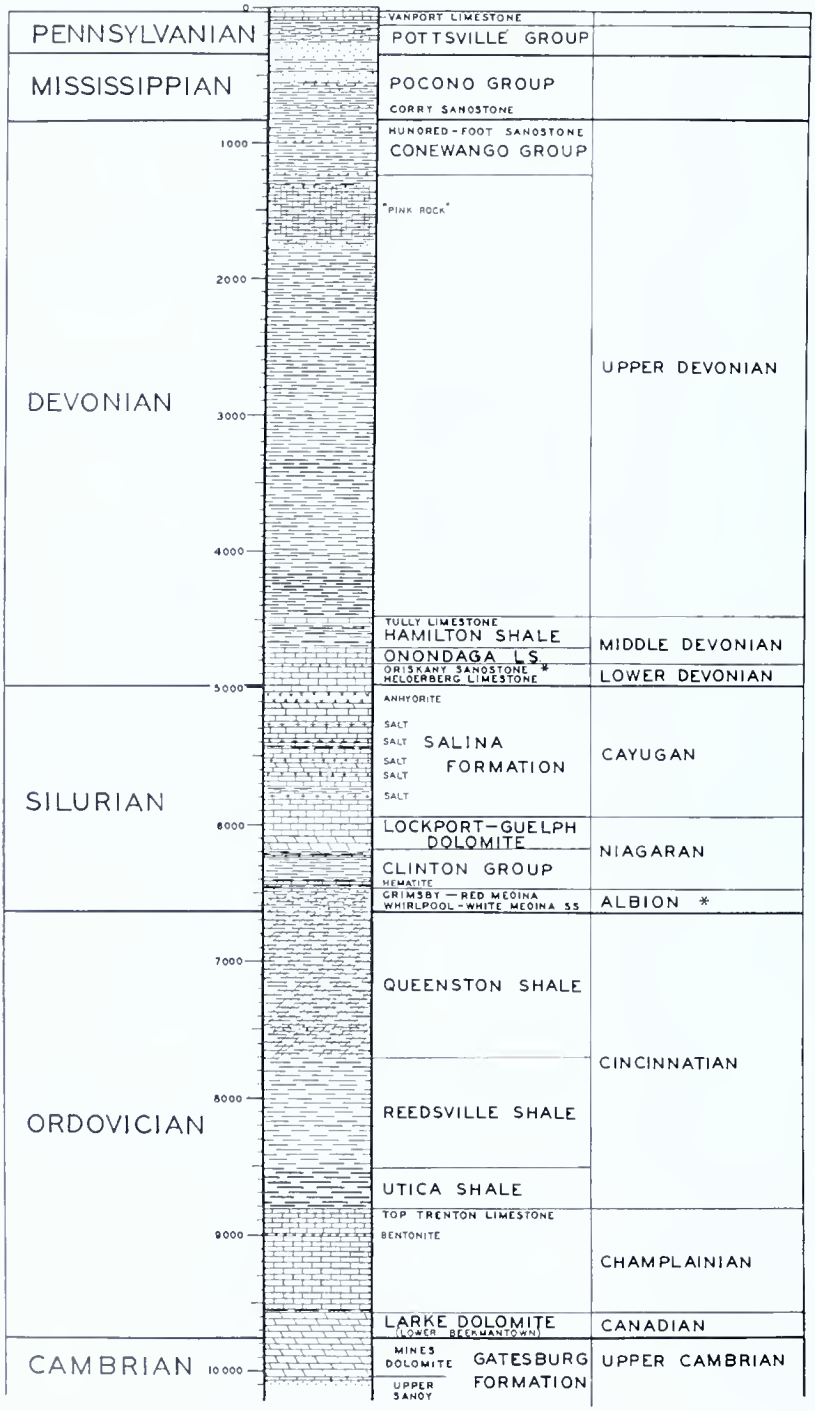
The major part of the oil production in Pennsylvania and large volumes of gas have come from the Upper Devonian sandstones. The Conewango, Conneaut, and Canadaway Formations are contained in this section. The most important is the Conewango which contains a large number of gas storage reservoirs. The Fifth sand is used as a



COLUMNAR SECTIONS SHOWING
STRATIGRAPHIC POSITIONS OF OIL AND GAS SANDS
OF WESTERN PENNSYLVANIA

JOHN M BERGSTEN, 1937

Plate 6.



COLUMNAR SECTION
WESTERN PENNSYLVANIA
OBTAINED IN JESSIE G. HOCKENBERRY WELL NO. 1
MANUFACTURERS LIGHT & HEAT COMPANY
MERCER TOWNSHIP, BUTLER COUNTY, PA.

* *CURRENT NATURAL GAS STORAGE HORIZONS*

CHAS R FETTKE 1953

Plate 7.

storage reservoir in one of the largest storage fields in the state, the Oakford Field in Westmoreland County. The lower part of the Upper Devonian is composed of unimportant shales and sandy shales. Suitable storage reservoirs of Upper Devonian age have yet to be found in northeastern Pennsylvania.

In the Middle Devonian, the Onondaga limestone and chert extend at depth over western and northeastern Pennsylvania. The Onondaga is gas productive in fracture-type porosity in the southern half of the western part of the state. Storage possibilities in this horizon should be of interest in the future.

The Oriskany sand of Lower Devonian age is the state's most important storage horizon. It is productive of gas in numerous areas. Although deeply buried, there are nine active Oriskany pools on anticlinal traps or up-dip pinchouts. More gas is stored in the Oriskany than in any other horizon. Other suitable reservoirs on anticlinal structures are yet to be developed.

The Salina Group of Silurian age underlies the entire plateau area of north-central and western Pennsylvania. The Salina is composed of beds of rock salt, individual salt layers ranging from less than 5 feet to nearly 200 feet in thickness. Salt beds sometimes possess combined thicknesses of over 650 feet and occupy intervals in the Salina ranging from less than 50 feet to over 1,200 feet. The uppermost salt bed is encountered at a depth of about 2,000 feet in Erie County and approximately 10,000 feet in the synclinal areas of the Allegheny Mountains Section. The thick salt deposits are suited for liquid storage in washed-out cavities. The beds are generally at a depth greater than other suitable rocks in the same area. There is no reason to consider this group for gas storage at this time.

The Medina Sandstone of Lower Silurian age is of interest in extreme northwestern Pennsylvania where the beds are about 3,500 feet in depth. A storage pool in Erie County utilizes the Medina Sandstone.

The Gatesburg Sandstone of Upper Cambrian age might become important as a storage reservoir. Although at great depth, it has porosity and permeability as shown by its production of saltwater when penetrated. Possibly the Gatesburg will be of interest in the future. This horizon has been used in Missouri as a gas storage reservoir in an aquifer.

The other Ordovician and Cambrian rocks and the Precambrian rocks are of little interest at the present. In large market areas, man-made cavities in these rocks might be used for storage of natural gas.

UNCONFORMITIES

In the Paleozoic section in Pennsylvania there are three unconformities occurring between the Pennsylvanian and the Mississippian Systems, the Devonian and Silurian Systems, and the Middle and Lower Ordovician Series.

The Pottsville Sandstone of the Pennsylvanian System in northwestern Pennsylvania rests upon the Knapp Formation, the basal formation of the Mississippian System, while in southwestern Pennsylvania the Pottsville overlies the Mauch Chunk Shale, the youngest formation of the Mississippian.

Except for the Coastal Plain and Triassic sediments, all rocks southeast of the Valley and Ridge Province are of Ordovician age or older.

A section of the Lower Ordovician, which is represented by approximately 4,500 feet of strata in central Pennsylvania, is missing in deep wells in westernmost Pennsylvania.

STRUCTURE

Pennsylvania lies in the Appalachian Basin, a broad asymmetrical structural trough or synclinorium. The basin is modified by a series of minor folds with axes trending northeast and southwest approximately parallel with the long axis of the trough. On the steep southeast limb, these consist of strong, well-defined anticlines and synclines.

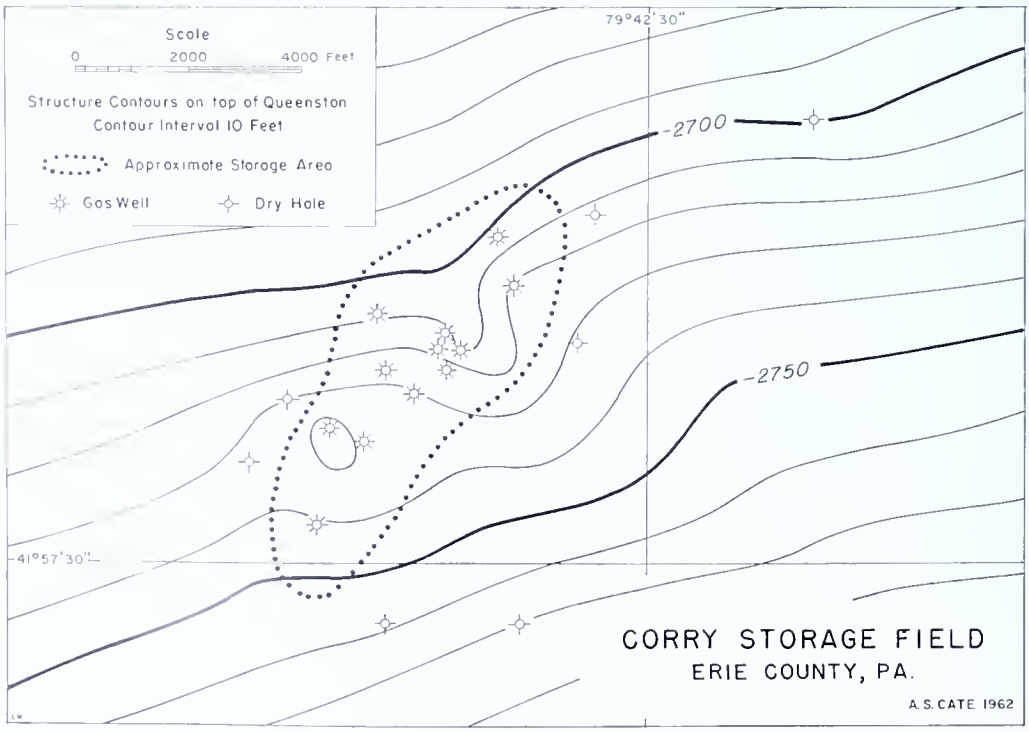


Figure 1.

Northwestward the intensity of the folding diminishes so that the folds become less prominent in the central part of the basin and disappear in the northwest part. The northwesternmost major fold is the Chestnut Ridge Anticline extending from West Virginia to the northeast, diagonally across Pennsylvania to the New York State line. This anticline marks the western boundary of the Allegheny Mountain Section. The rocks in the Plateaus Province dip to the south and southeast at 25 feet to 35 feet to the mile except where minor folding has taken place. Thus rocks at the surface in Erie County are 3,000 feet below the earth's surface in southwestern Pennsylvania.

It has been revealed by deep drilling that the folds at depth are much more complex structurally than had been anticipated by surface mapping. The domes along the anticlinal axis at the Oriskany horizon have been complexly and extensively modified by the commonly northwest-dipping reverse faults.

GAS STORAGE PROJECTS IN PENNSYLVANIA

Pennsylvania had 61 active natural gas storage pools or fields, both shallow and deep, at the close of 1959 (Table 2). The natural gas is stored in depleted gas pools in rocks from Silurian to Pennsylvanian in age and from 1,000 feet to 6,000 feet in depth. The storage pools occupy stratigraphic rather than structural traps in Pennsylvanian, Mississippian, Upper Devonian, and Lower Silurian (Medina) strata. In contrast, the gas stored in the Oriskany Sandstone (Lower Devonian age) pools occupies structural traps consisting of elongated domes along the prominent anticlines.

Structure maps of the gas storage pools in rocks of Lower Devonian age or older are published in this report: Figure 1, Corry Storage Field; Plate 8, Harrison Storage Pool; Plate 9, Hebron Storage Pool; Plate 10, Leidy Storage Field; Plate 11, Meade Storage Field; Plate 12, Sabinsville Storage Field; Plate 13, Sharon Storage Field; and Plate 14, Tioga Storage Field.

Leidy Storage Field (Plate 10) consists of the Leidy and Greenlick Pools. Since the Greenlick Pool was not used for gas storage until 1961 it is not shown on Plate 1 nor on Table 2 because the data shown on the two illustrations ends with the year 1959. The Greenlick Pool is not being used at its full capacity. At present the total amount of gas stored in the reservoir, including 3,550,000 Mcf of native gas, is about 8,550,000 Mcf, the cushion gas being 6,550,000 Mcf and the working gas 2,000,000 Mcf at a rock pressure of 944 psi. In Pennsylvania the gas storage pool underlying the most acreage is the Leidy Pool with 15,120 acres and a total reservoir capacity or 95,000,000 Mcf.

Table 2 — Natural Gas Storage Projects in Pennsylvania

Map No.	County and Project	Township	Gas Utility	Discovery Year	Wells	Acres of Storage Formation	Acres Controlled	Average Production Depth (ft.)	Average Sand Thickness (ft.)	Date of First Injection	Capacity MMcf			Storage Formation	Maximum Storage Pressure (psi)
											Working Gas	Cushion Gas	Total Reservoir		
	ALLEGHENY														
1	Gamble-Hayden	Forward	Peoples Nat. Gas. Co.	1929	14	600	1,641	2,775	20	1943	1,100	1,200	2,300	Bayard	1,000
2	Mt. Royal	Shaler	Peoples Nat. Gas Co.	1917	7	100	424	1,656	20	1949	225	275	500	Thirty Foot	500
3	Murrysville	Plum	Peoples Nat. Gas Co.	1916	16	350	1,453	1,875	30 pay	1939	1,500	1,600	3,100	Hundred Foot	1,000
4	Tarentum Stone & Coal	Frazer	T. W. Phillips Gas & Oil Co.		1	10	79	1,557	20 net	1948	—	—	—	Boulder	53
5	Tepe	Jefferson	Equitable Gas Co.	1928	6	470	996	2,280	5 net	1936	1,380	320	1,700	Fifth	1,000
	ALLEGHENY & WASHINGTON														
6	Bunola	Forward, Union	Equitable Gas Co.	1895	28	1,980	3,028	2,040	12 net	1937	4,220	1,280	5,500	Gantz	750
	ARMSTRONG & INDIANA														
7	South Bend	South Bend, Armstrong & Plum Creek	New York State Nat. Gas Corp.	1923	70	3,300	10,388	1,600	100	1951	6,600	10,500	17,100	Hundred Foot	630
	BUTLER														
8	Hughes	Buffalo	T. W. Phillips Gas & Oil Co.		1	12	85	2,020	13 net	1955	—	—	—	Fifth	815
9	Neubert	Jefferson	Saxonburg Ht. & Lt. Co.	1920	1	25	40	1,400	30 net	1953	5	2	7	Murraysville	140
10	Portman	Summit	T. W. Phillips Gas & Oil Co.		2	30	151	1,581	24 net	1942	—	—	—	Fifth	407
11	Saxonburg	Jefferson	Saxonburg Ht. & Lt. Co.	1947	4	115	230	1,800	30	1954	20	10	30	Venango Fourth	40
	CLARION														
12	Truittsburg	Red Bank	Peoples Nat. Gas Co.	1925	24	750	3,002	1,562	20	1949	2,100	1,500	3,600	Bayard	900
	CLINTON & POTTER														
13	Leidy	East Keating, Grove, Leidy, Stewardson	New York State Nat. Gas Corp. (Operator) Transcontinental Gas Pipeline Corp. Texas Eastern Transmission Co. (operator)	1950	71	15,120	54,263	6,050	30	1959	54,000	41,000	95,000	Oriskany	4,000

Table 2 — Natural Gas Storage Projects in Pennsylvania (continued)

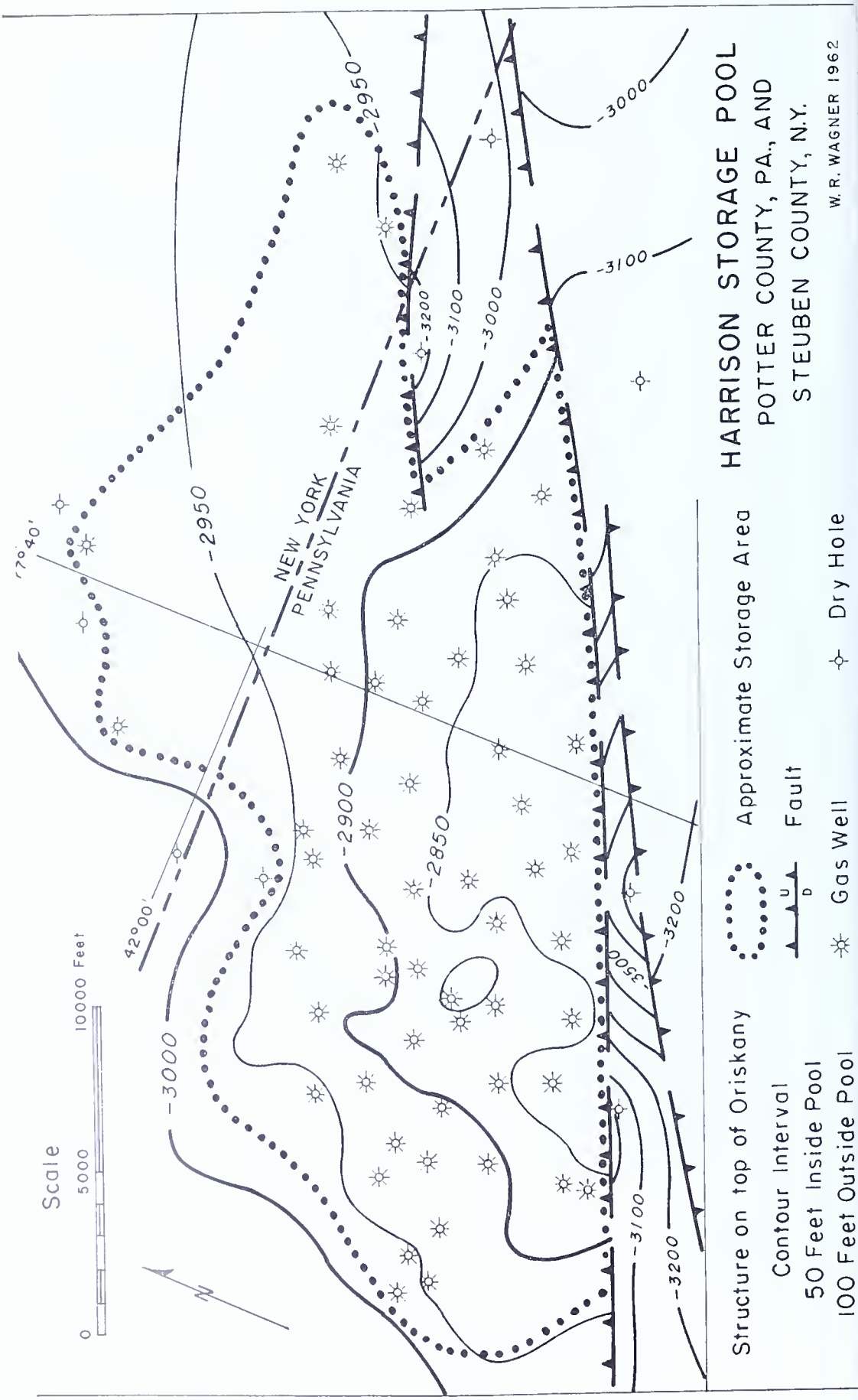
Map No.	County and Project	Township	Gas Utility	Discovery Year	Wells	Acres of Storage Formation	Acres Controlled	Average Production Depth (ft.)	Average Sand Thickness (ft.)	Date of First Injection	Capacity MMcf: Working Gas	Capacity MMcf: Cushion Gas	Capacity MMcf: Total Reservoir	Storage Formation	Maximum Storage Pressure (psi)
	ELK														
14	Belmouth		United Nat. Gas Co.	1915	22	—	—	1,900	10	1938	450*	450	900	Cooper	700 Original RP
15	Boone Mt.		United Nat. Gas Co.	1901	31	—	—	1,230	45	1947	800*	650	1,450	Fifth Venango	500 Original RP
16	Mohan Run		United Nat. Gas Co.	1924	19	—	—	2,360	20	1949	70*	0	70	Elk	635 Original RP
17	Owls Nest	Highland & Spring Creek	Pennsylvania Gas Co.	1908	38	987	—	1,930	29	1949	900	900	1,800	Tiona	650 (three small projects)
18	St. Marys		United Nat. Gas Co.	1916	15	—	—	1,330	40	1936	180*	100	280	Fifth Venango	590 Original RP
	ERIE														
19	Corry	Wayne	Pennsylvania Gas Co.	1947	10	832	—	4,520	13	1955	300	300	600	Medina	1,200
20	Meade (Summit)	Summit	Pennsylvania Gas Co.	1946	49	2,147	—	2,350	10	1959	2,800	1,900	4,700	Oriskany	800
	FOREST														
21	Duhring	Jenks	Pennsylvania Gas Co.	1941	6	56	—	930	31	1947	150	100	250	Deemer	225
	GREENE														
22	Holbrook	Center	Manufacturers Lt. & Ht. Co.	1920	18	1,316	4,320	2,850	25	1950	700	500	1,200	Hundred Foot	1,000
23	Hunters Cave	Center & Morris	Equitable Gas Co.	1917	16	1,694	4,162	2,172	10 net	1942	1,880	920	2,800	Big Injun	950
24	Kirby	Perry & Whiteley	Equitable Gas Co.	1926	23	5,423	7,453	2,681 3,082	6 net 4 net	1945	1,975	925	2,900	Gantz & Fifth	950
25	Swartz	Morris & Washington	Equitable Gas Co.	1922	6	523	1,126	2,750	14 net	1949	1,504	136	1,640	50 Foot	1,000
	GREEN & WASHINGTON														
26	Pratt	Morgan, Washington, & W. Bethlehem	Equitable Gas Co.	1902	45	5,567	11,275	2,498 2,845	6 net 11 net	1947	3,890	1,320	5,210	50 Foot Fifth	650
27	Heard	Richhill & W. Finley	Manufacturers Lt. & Ht. Co.	1907	57	3,487	10,188	2,510	240, 12, 15, 13, 9	1943	3,500	5,800	9,300	Big Injun, 50 Foot; 30 Foot, Gordon Stray, & Gordon	900
28	Majorsville (partly in W. Va.)	Richhill & W. Finley	Manufacturers Lt. & Ht. Co.	1905	177	8,736	23,603	1,370 shallow 2,510 deep	16, 23, 290, 13, 15, 13, 9, 8	1937	10,500	19,500	30,000	Gas Sd, Salt Sd, Big Injun, 100 Foot; 30 Foot; Gordon Stray, Gordon, Fifth	600 (Shallow) 900 (deep)

	INDIANA															
29	Alabran	W. Mahoning & N. Mahoning	T. W. Phillips Gas & Oil Co.		10	294	883	2,062	28 net	1955	—	—	—	Murraysville. 100 Foot, Venango Third, Sheffield, Bradford	252
30	Kinter	S. Mahoning & E. Mahoning & Rayne	T. W. Phillips Gas & Oil Co.		14	240	1,359	1,740	35 net	1949	—	—	—	Murraysville, 100 Foot; 30 Foot; Boulder; Venango Third; Bradford, Kane	312
	JEFFERSON															
31	Bullers		United Nat. Gas Co.	1922	9	—	—	810	15	1950	40*	10	50	U. Murraysville	260 Original RP
32	Galbraith		United Nat. Gas Co.	1917	36	—	—	2,870	25	1937	940*	660	1,600	1st Sheffield	620 Original RP
33	Iowa	Knox & Pine Creek	Manufacturers Lt. & Ht. Co.	1909	4	622	1,359	1,375	16	1945	125	175	300	Elizabeth	550
34	Markle		United Nat. Gas Co.	1921	8	—	—	1,590	15	1938	100*	240	340	Fifth Venango	625 Original RP
35	Munderf	Warsaw	Manufacturers Lt. & Ht. Co.	1926	1	92	678	2,400	22	1943	50	0	50	Speechley	500
36	Sprankle	Perry & Young	T. W. Phillips Gas & Oil Co.		12	198	1,106	1,588	30 net	1954	—	—	—	Murraysville, Hundred Foot; 30 Foot, Snee Boulder, Bradford	250
	McKEAN															
37	Keelor	Hamilton & Wetmore	Pennsylvania Gas Co.	1906	30	1,607	—	1,930	31	1946	1,400	1,400	2,800	Cooper	500
38	Meade Run	Wetmore	Kane Gas Lt. & Ht. Co.	1900	14	195	2,500	800	15	1942	57	60	117	Clarion	350
39	Swede Hill	Hamilton	Pennsylvania Gas Co.	1903	28	956	—	1,810	71	1950	500	500	1,000	Tiona	600
40	Wellendorf		United Nat. Gas Co.	1904	19	—	—	1,160	25	1929	265*	615	880	Fifth Venango	450 Original RP
	McKEAN & WARREN															
41	East Branch "A"	Hamilton, Wetmore & Sheffield	Pennsylvania Gas Co.	1888	75	4,275	—	1,960	25	1948	1,100	1,500	2,600	Cooper	240
42	East Branch "B"	Hamilton & Sheffield	Pennsylvania Gas Co.	1889	82	2,427	—	1,950	63	1953	3,600	1,900	5,500	Cooper	350
	MERCER & VENANGO															
43	Henderson		United Nat. Gas Co.	1899	93	—	—	910	35	1934	1,600*	1,150	2,750	First Venango Third Venango	300 Original RP Est.
	POTTER															
44	Harrison (partly in N.Y.)	Bingham, Harrison & Brookfield	New York State Nat. Gas Co.	1934	55	10,800	29,389	4,989	27	1953	19,680	13,120	32,800	Oriskany	2,000

Table 2 — Natural Gas Storage Projects in Pennsylvania (continued)

Map No.	County and Project	Township	Gas Utility	Discovery Year	Wells	Acres of Storage Formation	Acres Controlled	Average Production Depth (ft.)	Average Sand Thickness (ft.)	Date of First Injection	Capacity MMcf			Storage Formation	Maximum Storage Pressure (psi)
											Working Gas	Cushion Gas	Total Reservoir		
45	Hebron		United Nat. Gas Co. & Tenn. Gas Transmission Co.	1931	53	est. 3,500	est. 7,500	5,160	20	1953	22,500	23,800	46,300	Oriskany	2,200
46	Sharon	Sharon & Oswayo	New York State Nat. Gas Co.	1938	14	1,333	3,955	4,827	13	1948	1,900	4,200	6,100	Oriskany	860
	TIOGA														
47	WestTioga(Palmer)	Farmington	North Penn Gas Co.	1930	19	—	8,745	4,000	10	1935	8,200	1,800	10,000	Oriskany	1,500
48	Meeker	Farmington	North Penn Gas Co.	1930	19	—	8,745	4,000	10	1935	4,800	200	5,000	Oriskany	1,500
49	Sabinsville	Clymer, Westfield & Chatham	New York State Nat. Gas Co.	1935	28	6,800	15,407	4,600	15	1951	15,450	18,000	33,450	Oriskany	2,200
50	East Tioga (Boom)	Lawrence & Farmington	New York State Nat. Gas Co.	1930	34	5,116	9,142	4,000	35	1940	20,800	14,000	34,800	Oriskany	1,500
	WARREN														
51	Deerlick	Sheffield	Pennsylvania Gas Co.	1888	30	1,660	—	1,390	13	1950	100	0	100	Tiona	100
	WARREN & FOREST														
52	Queen		United Nat. Gas Co.	1889	22	—	—	1,200	80	1920	150*	300	450	Queen	400 Original RP Est.
	WASHINGTON														
53	Colvin	Fallowfield	Peoples Nat. Gas Co.	1924	9	530	1,176	2,300	30	1943	800	1,500	2,300	Murraysville	685
54	Cross Creek	Jefferson	Manufacturers Lt. & Ht. Co.	1901	16	1,855	5,286	1,950	12	1937	125	900	1,025	Hundred Foot	200
55	Donegal	Donegal	Manufacturers Lt. & Ht. Co.	1907	81	3,563	15,433	2,650	12	1940	3,400	4,000	7,400	Gordon Stray	1,000
56	Finleyville	Union	Equitable Gas Co.	1927	4	221	576	2,621	8 net	1934	487	73	560	Fifth	1,000
	WESTMORELAND														
57	Irwin	North Huntington	Manufacturers Lt. & Ht. Co.	1917	3	407	14	548	24	1942	25	325	350	Elizabeth	225
58	Oakford	Salem, Penn & Hempfield	New York State Nat. Gas Co.	1885 1907	269	13,548	34,562	1,400 2,200	100 60	1951 1951	51,408 8,592	36,850 13,908	88,258 22,500	Murraysville Fifth	267 1,143
59	Patton	Rostraver	Peoples Nat. Gas Co.	1924	1	70	300	2,122	25	1948	75	75	150	Murraysville	600
60	Trafford	Penn	Duquesne Nat. Gas Co.	1923	5	158	1,000	2,250	35	1948	150	50	200	Fifth	300
61	Webster	Rostraver	Peoples Nat Gas Co.	1923	6	600	1,993	2,179	30	1945	540	600	1,140	Murraysville	600

*Data obtained from Oil & Gas Journal


HARRISON STORAGE POOL
POTTER COUNTY, PA., AND
STEUBEN COUNTY, N.Y.
W. R. WAGNER 1962
Structure on top of Oriskany
Contour Interval
50 Feet Inside Pool
100 Feet Outside Pool
Approximate Storage Area
Fault
Gas Well
Dry Hole
Scale
0
5000
10000 Feet
N
NEW YORK
PENNSYLVANIA
-2950
-2900
-2850
-3000
-3100
-3200
-3500
42°00'
77°40'

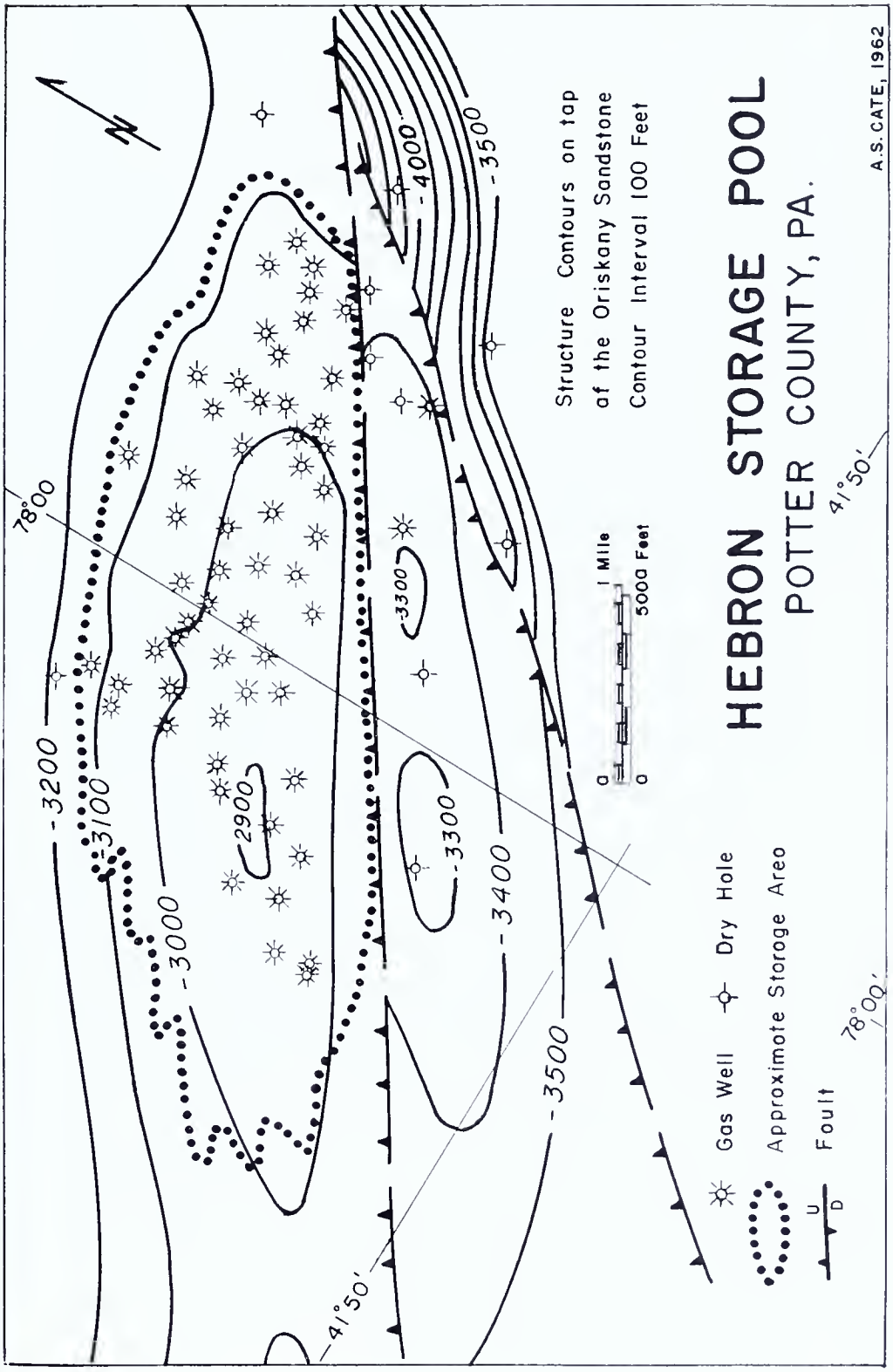

HEBRON STORAGE POOL
POTTER COUNTY, PA.
Structure Contours on top of the Oriskany Sandstone
Contour Interval 100 Feet
A.S. CATE, 1962
Gas Well
Dry Hole
Approximate Storage Area
Fault
U
D
0
1 Mile
0
5000 Feet
-3200
-3100
-3000
-2900
-3300
-3300
-3400
-3500
-3500
-4000
-3500
78°00'
41°50'
78°00'
41°50'

Plate 9

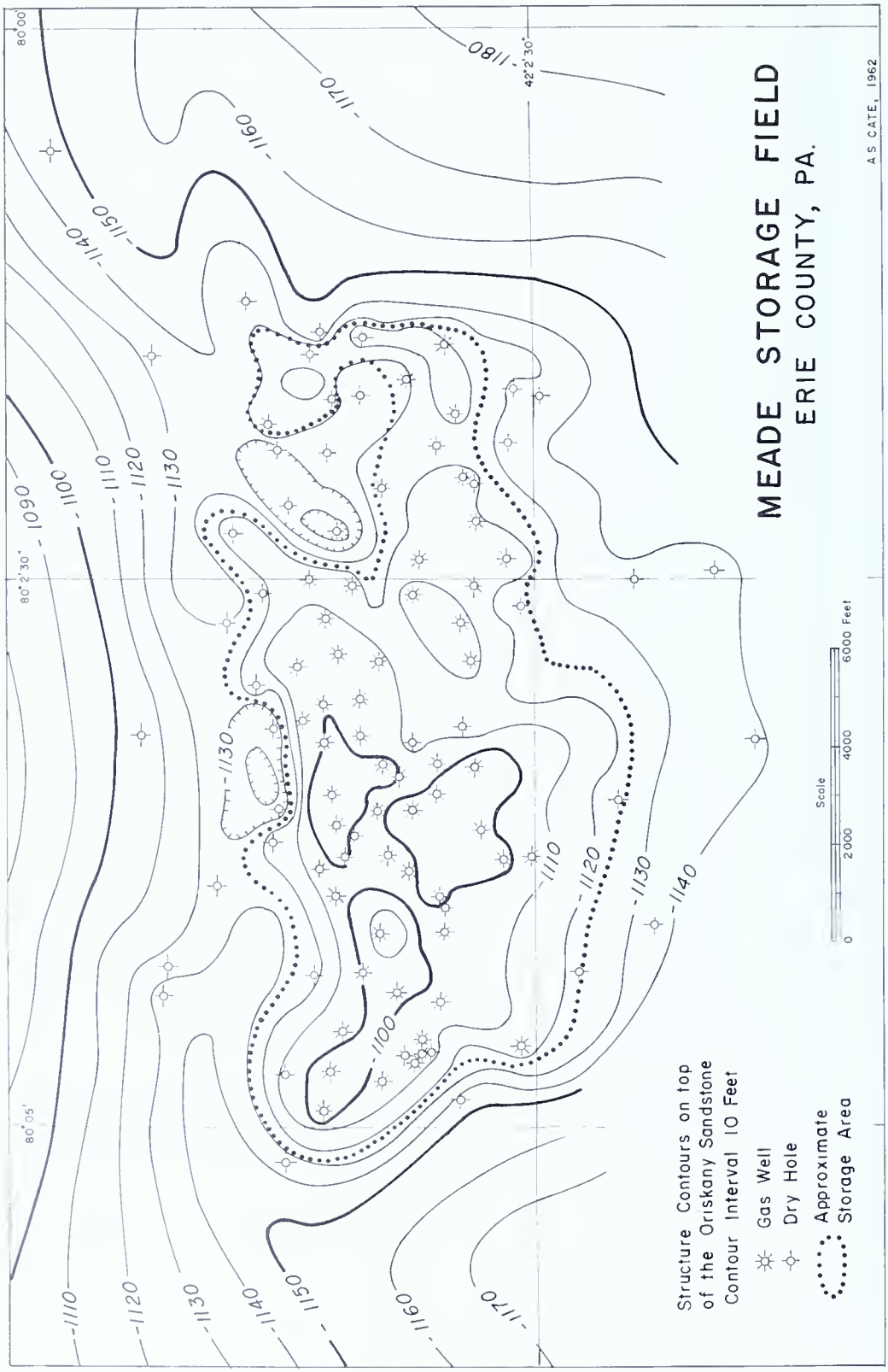

MEADE STORAGE FIELD
ERIE COUNTY, PA.
A.S. CATE, 1962
Structure Contours on top of the Oriskany Sandstone
Contour Interval 10 Feet
Gas Well
Dry Hole
Approximate Storage Area
Scale
0
2000
4000
6000 Feet
80°00'
80°2'30"
80°05'
42°2'30"
1090
1100
1110
1120
1130
1140
1150
1160
1170
1180

Plate II

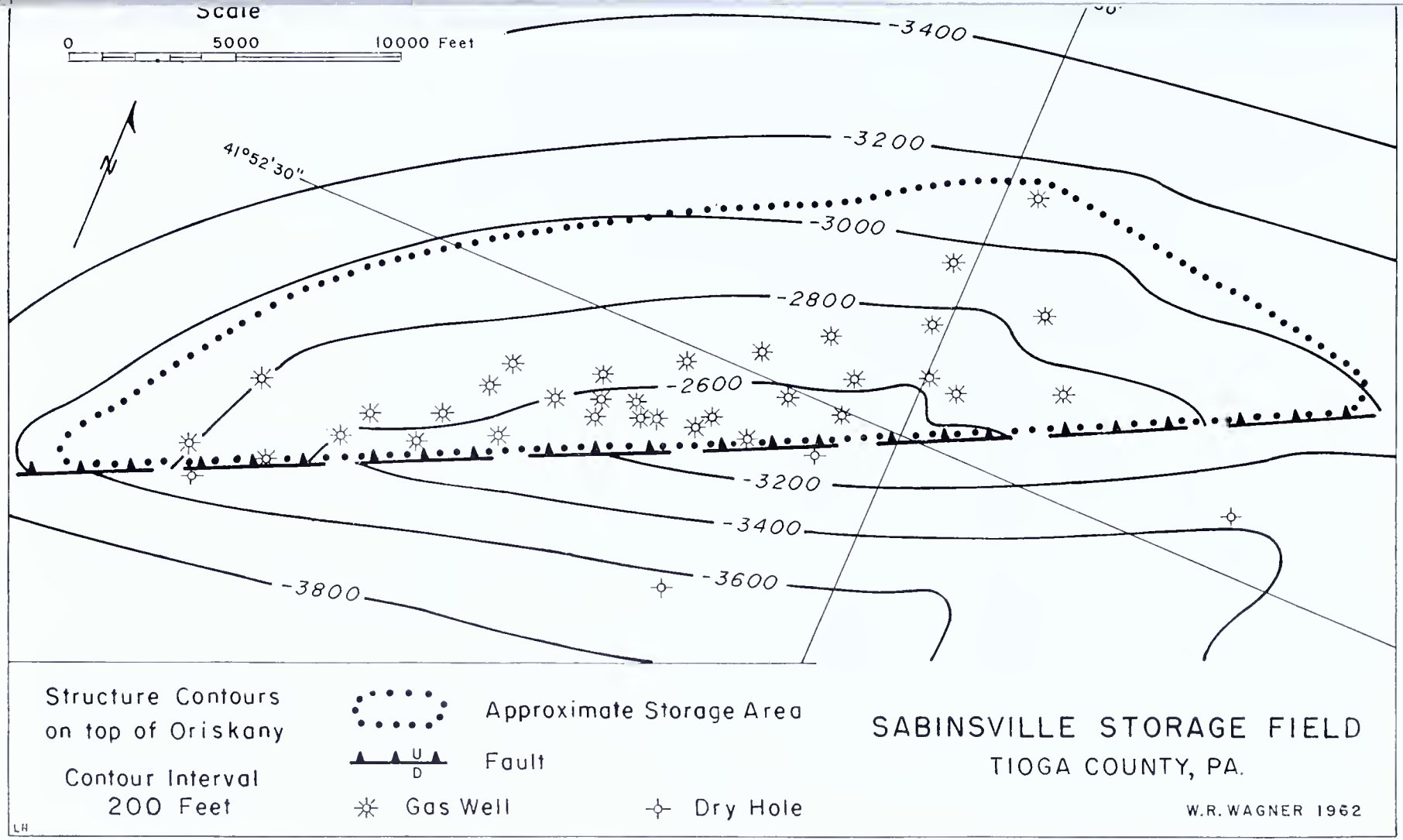

Scale
0
5000
10000 Feet
N
41°52'30"
-3400
-3200
-3000
-2800
-2600
-3200
-3400
-3600
-3800
Structure Contours
on top of Oriskany
Contour Interval
200 Feet
Approximate Storage Area
U
D
Fault
Gas Well
Dry Hole
SABINSVILLE STORAGE FIELD
TIOGA COUNTY, PA.
W.R. WAGNER 1962
LH

Plate 12.

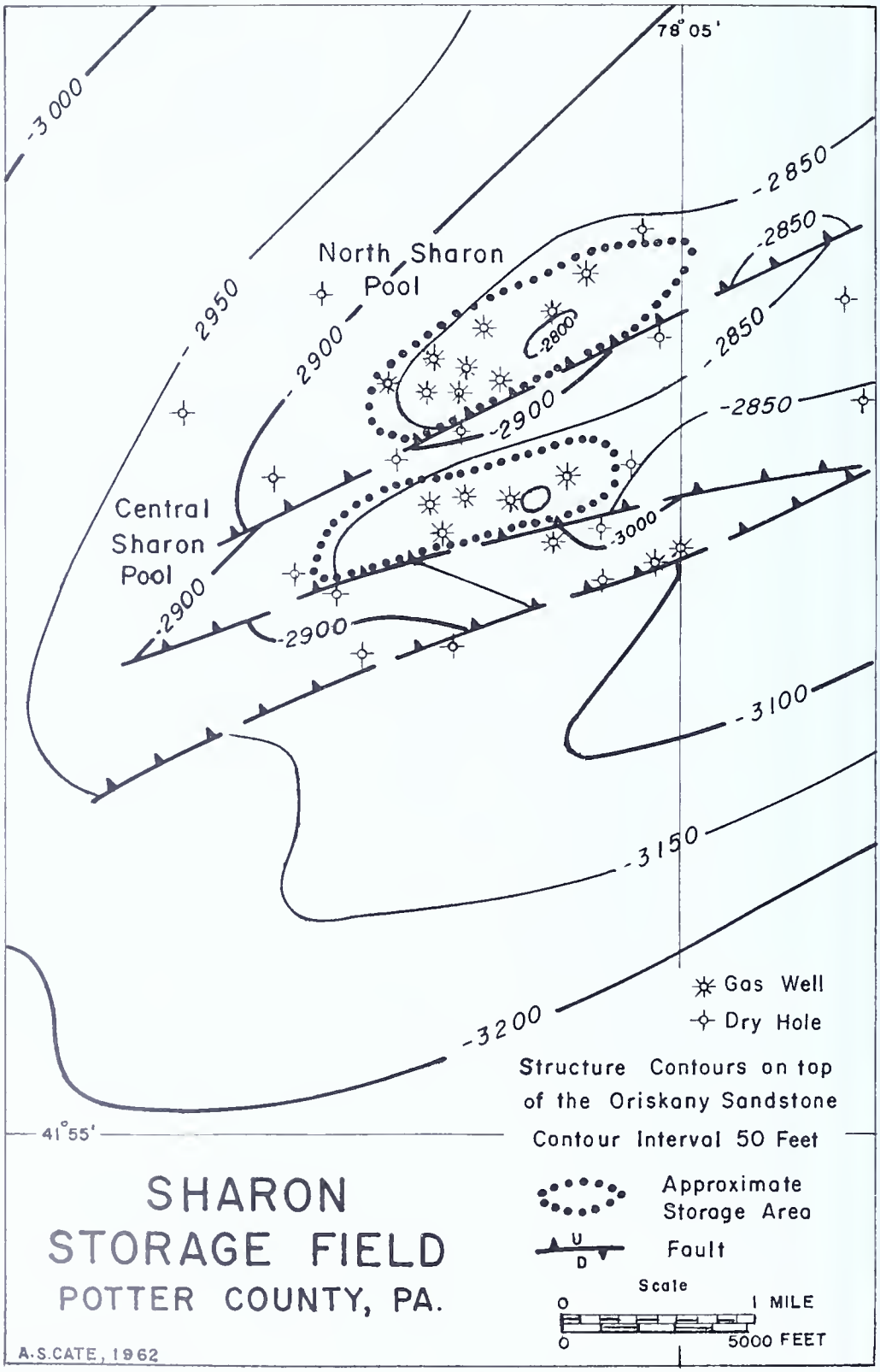

78°05'
-3000
-2950
-2900
-2850
North Sharon Pool
Central Sharon Pool
-2800
-3000
-3100
-3150
-3200
41°55'
Gas Well
Dry Hole
Structure Contours on top of the Oriskany Sandstone
Contour Interval 50 Feet
Approximate Storage Area
Fault
U
D
Scale
0
1 MILE
0
5000 FEET
SHARON STORAGE FIELD
POTTER COUNTY, PA.
A.S.CATE, 1962

Plate 13

The Oakford Storage Field covers 13,548 acres and has a reservoir capacity of 110,758,000 Mcf. The Oakford Storage Field is in Westmoreland County in the southwestern portion of the state (Plate 2, field 58) along the eastern flank of development on the Grapeville Anticline, a minor fold in the Appalachian Plateaus Province. The two principal producing sands in the area are the Murrysville and Fifth sands which are the gas storage reservoirs in the field.

The Murrysville is the shallower of the two sands, being 1,400 feet below the surface. It is about 100 feet thick with an average pay thickness of approximately 50 feet. The accumulation of gas in the Murrysville sand was due partly to structure. Gas accumulated in the top of the dome, limited along the axis of the anticline by saddles on each end. The low portion of the structure is effectively sealed by saltwater. This sand is very coarse and pebbly and has a porosity of about 20%.

Depth to the Fifth sand averages 2,200 feet. It is about 60 feet thick and has 20 feet of productive sand with an average porosity of 13%. The trap in the Fifth sand is due to porosity being sealed on its boundary by tight sand. The large number of wells drilled in this area has established the boundaries of both pools.

The first wells were drilled in the Murrysville sand in Oakford in 1887. The rock pressure was 600 psi plus, and well flows ranged from 10,000 Mcf to 40,000 Mcf per day. Fifth sand production was discovered in 1907 with an initial rock pressure of 1,100 psi and open flows from 20,000 Mcf to 30,000 Mcf per day.

The Murrysville sand has a working capacity of 51,408,000 Mcf and the Fifth sand 8,952,000 Mcf, making a total working capacity of 60,000,000 Mcf.

Natural gas storage figures for the year 1960 as published by the AGA show Pennsylvania as the ranking state in all phases of gas storage: the maximum gas in storage, 485,000,000 Mcf; total input, 227,000,000 Mcf; maximum day output, 2,859,000 Mcf; total output, 177,000,000 Mcf; and ultimate capacity 497,000,000 Mcf.

REGULATION OF UNDERGROUND GAS STORAGE POOLS

The Pennsylvania Gas Operations, Well-Drilling, Petroleum and Coal Mining Act of 1955, known as Act 225, relates to coal mining, well operations, the underground storage of gas except in storage reservoirs excavated in rock formations specifically for storage purposes, and the safety of personnel and facilities employed therein.

Article 3 of the above act deals specifically with "Regulation of Underground Gas Storage Pools in Certain Areas." Section 301 of this article is concerned with the filing of maps and data by persons

operating or proposing to operate gas storage reservoirs within three thousand to ten thousand linear feet of an operating coal mine which is operating in a coal seam that extends over the storage reservoir or the reservoir protective area. The requirements of this section do not apply to the operator of an underground gas storage reservoir if the reservoir is located more than ten thousand linear feet from an operating coal mine and provided that a location map of the gas storage reservoir is filed with the Oil and Gas Division carrying out the provisions of this act. Section 302 requires the filing of maps and data by persons operating coal mines. Section 303 concerns notices to be sent to the Oil and Gas Division by persons operating coal mines within 2,000 linear feet of a gas storage reservoir. Section 304 states the obligations of persons operating storage reservoirs which underly or are within two thousand linear feet of an operating coal mine which is operating in a coal seam that extends over the storage reservoir or the reservoir protective area. Section 305 has to do with the inspection of facilities and records, the reliance on the most recent maps for locations, and the burden of proving the accuracy of the map or data. Section 306 exempts certain types of coal mines from the provisions of the act, prohibits the injection of gas for storage purposes in any workable coal seam, and makes sure that Article 3 is not construed so as to prohibit the original extraction of natural gas, crude oil, or coal.

Article 4 of Act 225 deals with "Eminent Domain". Section 401 of this article provides that the right of eminent domain shall not be exercised to acquire for the purpose of gas storage any geological stratum unless the original recovery oil or gas reserve therein has been depleted at least 80%, until the condemnor has acquired at least 75% of the area of the proposed reservoir. The right of eminent domain cannot be exercised in any area where gas is already being stored. The owner of nonstorage strata in a storage area may drill wells for the purpose of producing oil or gas from any stratum above or below the storage stratum so long as the storage stratum is being adequately protected to prevent the escape of the stored gas.

CONCLUSIONS

The completion of pipelines carrying western gas to the eastern states, the depletion of our own reserves, and the great market demand for natural gas has stepped up the development of natural gas storage pools in Pennsylvania. Several storage projects are being developed, but more are needed. In western Pennsylvania, geologic conditions are favorable for the economical storage of natural gas in porous rocks of Pennsylvanian to Silurian age. Although most of the same rocks occur in the northeastern part of the state, suitable

reservoir rocks have not yet been found in this area. Nor have suitable traps been found in the southeastern part of the state. At present the only solution in the southeastern section is man-made cavities for the storage of gas.

Where large population centers and industries are located in the western part of the state we also find natural gas reservoirs at comparatively shallow depths. There are a number of oil and gas reservoirs in this area which are possible gas storage pools. The conversion of some of the present Oriskany gas pools to storage pools will increase the storage facilities considerably.

Pennsylvania has numerous coal mines. As the development of gas storage in coal mines progresses, some of Pennsylvania's mines might meet the requirements.

REFERENCES

Jefferies, R. S. (1952), *Oakford underground storage project*, The Petroleum Engineer, (Dec. 1960), p. D-35, D-36, D-38, D-40, D-42, D-43.

Fettke, Chas. R. (1953), *Oil and gas developments in the Appalachian Basin past and present*, Pa. Geol. Survey, 4th ser., Bull. M37.

——— (1955), *Occurrence of rock salt in Pennsylvania*, Pa. Geol. Survey, 4th ser., PR 145.

Willard, Bradford (1962), *Pennsylvania geology summarized*, Pa. Geol. Survey, 4th ser., Bull. ES 4.

Pennsylvania gas operations, well-drilling, petroleum and coal mining act of 1955, Commonwealth of Pennsylvania, Dept. of Mines and Mineral Industries, Oil and Gas Division, Act 225.

Summary of tenth report of subcommittee on underground gas storage statistics, American Gas Association 1961.

GAS STORAGE FIELDS OF PENNSYLVANIA

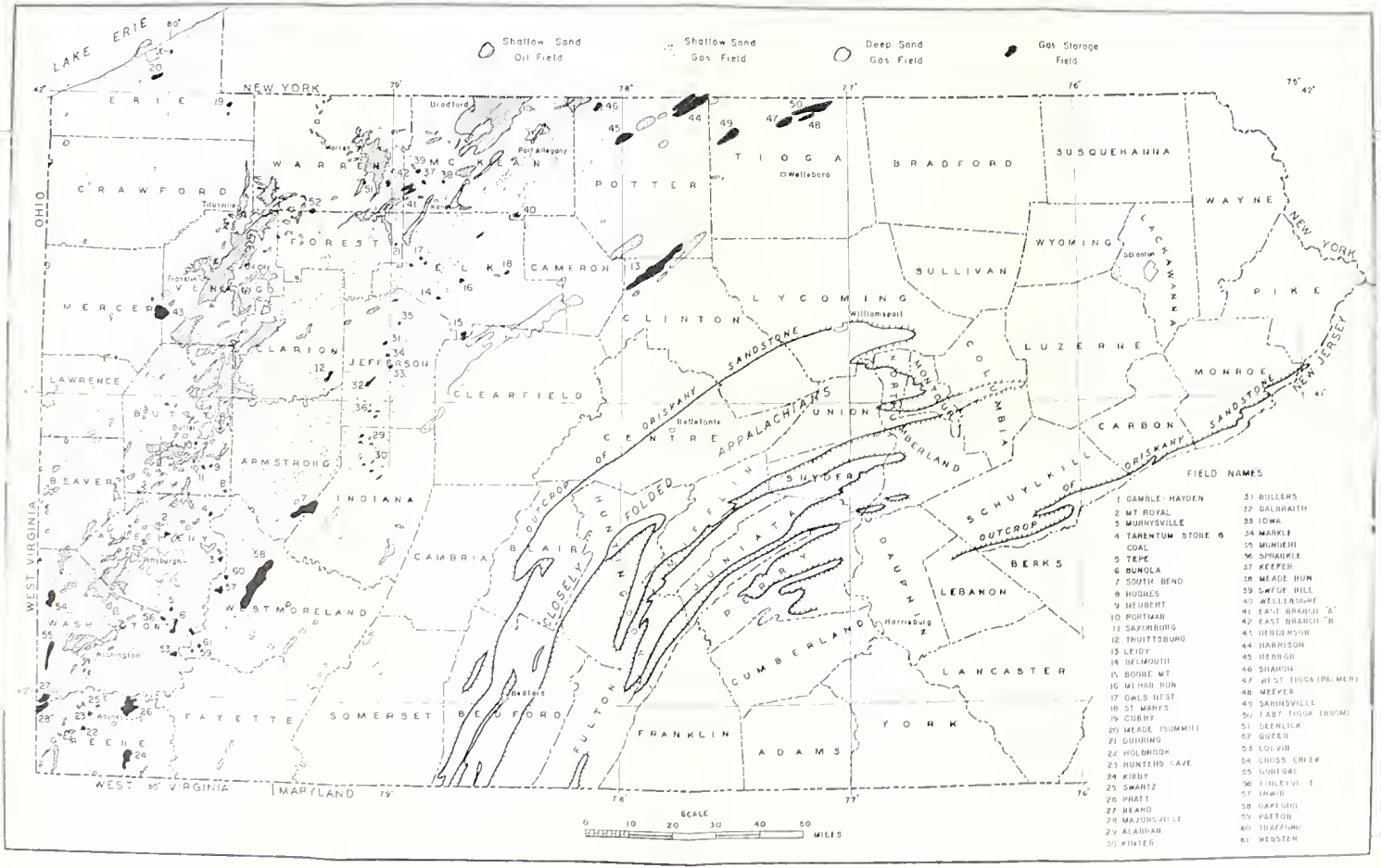


Plate I

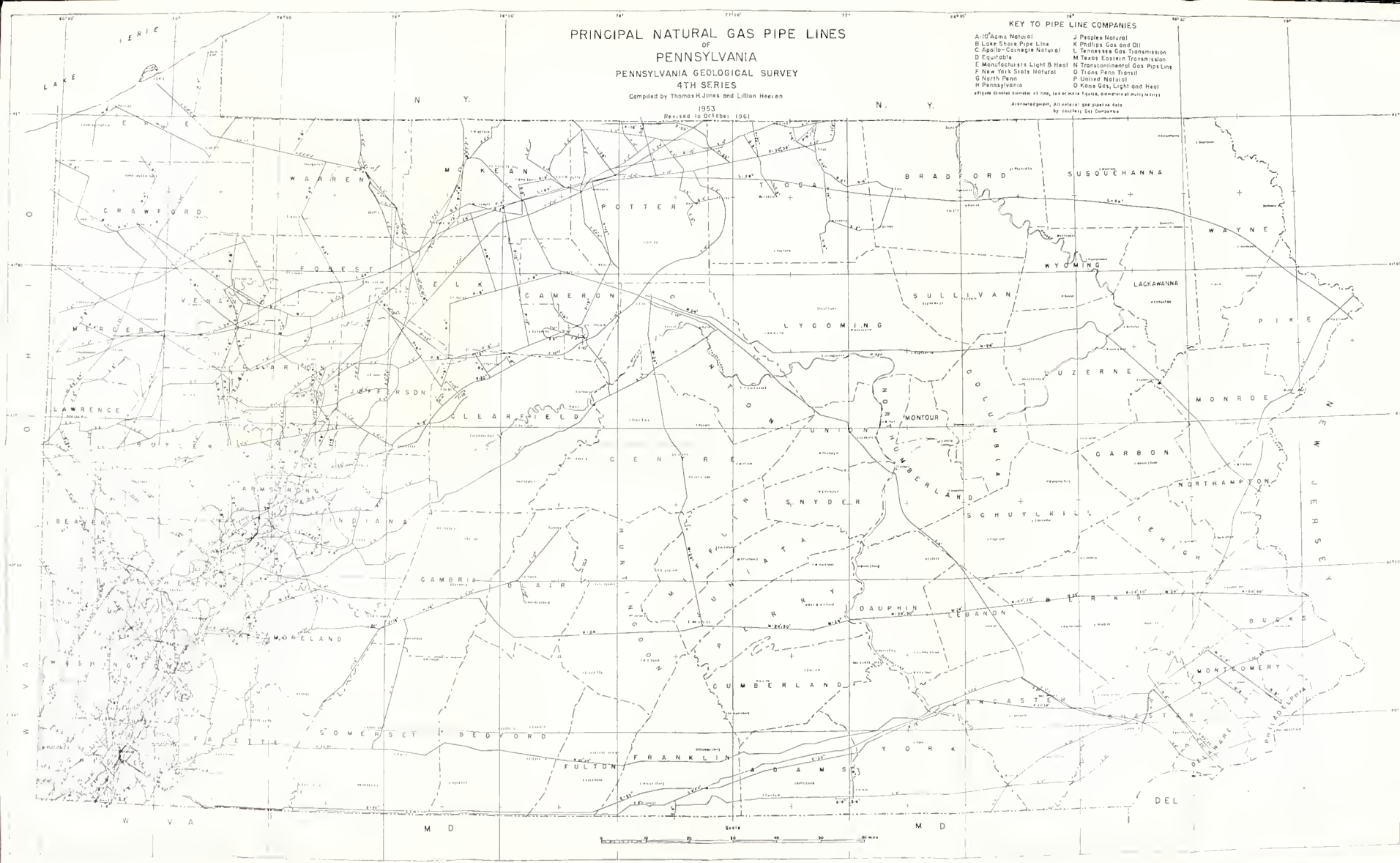

PRINCIPAL NATURAL GAS PIPE LINES
OF
PENNSYLVANIA
PENNSYLVANIA GEOLOGICAL SURVEY
4TH SERIES
Compiled by Thomas H. Jones and Lillian Heeren
1953
Revised to October 1961
KEY TO PIPE LINE COMPANIES
A-10"Acme Natural
B Lake Shore Pipe Line
C Apollo-Carnegie Natural
D Equitable
E Manufacturers Light & Heat
F New York State Natural
G North Penn
H Pennsylvania
J Peoples Natural
K Phillips Gas and Oil
L Tennessee Gas Transmission
M Texas Eastern Transmission
N Transcontinental Gas Pipe Line
O Trans Penn Transit
P United Natural
Q Kane Gas, Light and Heat
Acknowledgment, All natural gas pipeline data by courtesy Gas Companies
LAKE ERIE
N. Y.
N. Y.
OHIO
W. VA.
W. VA.
MD
MD
DEL
ERIE
WARREN
McKEAN
POTTER
TIOGA
BRADFORD
SUSQUEHANNA
WAYNE
CRAWFORD
FOREST
ELK
CAMERON
SULLIVAN
WYOMING
LACKAWANNA
PIKE
MERCER
VENANGO
CLARION
LYCOMING
LUZERNE
MONROE
LAWRENCE
JEFFERSON
CLEARFIELD
MONTOUR
COLUMBIA
CARBON
NORTHAMPTON
BUTLER
CENTRE
UNION
NORTHUMBERLAND
ARMSTRONG
SNYDER
SCHUYLKILL
LEHIGH
BEAVER
INDIANA
CAMBRIA
BLAIR
JUNIATA
PERRY
DAUPHIN
LEBANON
BERKS
BUCKS
WESTMORELAND
CUMBERLAND
MONTGOMERY
LANCASTER
CHESTER
PHILADELPHIA
DELAWARE
FAYETTE
SOMERSET
BEDFORD
FULTON
FRANKLIN
YORK
ADAMS
Scale
0 5 10 20 30 40 50 60 Miles

Plate 3.

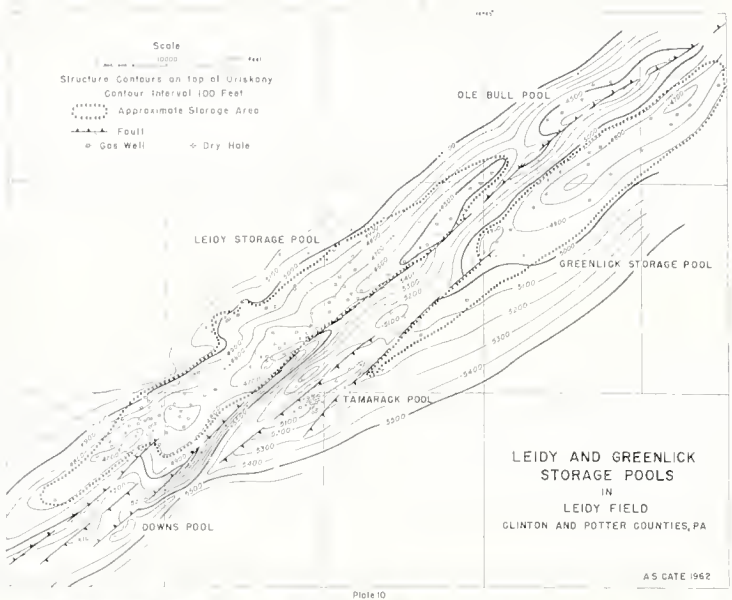


Plate 10

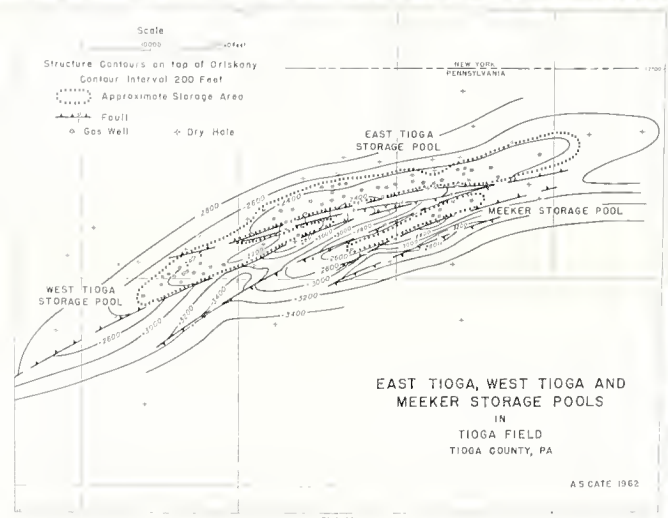


Plate 14